

DESCRIPTION

Title of Invention: MAGNETIC RECORDING DEVICE AND LAMINATED STRUCTURE

5 Technical Field

[0001] The present disclosure relates to a magnetic recording device and a laminated structure.

Background Art

[0002] With the recent development of computer technology, magnetic recording devices with a larger storage capacity and a smaller footprint are desired. To achieve this, for the magnetic
10 recording devices, a laminated structure that includes a plurality of magnetic disks and a spacer is formed by providing the spacer between the magnetic disks and passing a spindle through inner holes of the magnetic disks and the spacer. The magnetic disks and the spacer are fixed by being pressed by a clamp member from one side. In such a laminate, the magnetic disks do not
15 come into contact with each other, and are located at predetermined positions at an interval. In the magnetic recording devices, a magnetic head located in the space between the magnetic disks spaced apart from each other performs a recording operation and the like on the layered magnetic disks (for example, see PTL1 to PTL3).

Citation List

Patent Literature

20 [0003] [PTL1]: JP H8-315533A
 [PTL2]: JP 2000-57727A
 [PTL3]: JP 2003-272336A

Summary of Invention

Technical Problem

25 [0004] If the substrate of the magnetic disk and the spacer greatly differ in the coefficient of thermal expansion, the substrate may be broken due to expansion caused by changes in temperature during operation of the magnetic recording device. Producing the spacer using the same material as that of the substrate allows them to have the same coefficient of thermal expansion, thus making it possible to prevent breakage caused by changes in temperature.
30 However, it was found that when a thin substrate is used, changes in temperature of a usage

environment cause deformation of the substrate, which leads to deterioration of impact resistance and fluttering properties.

[0005] Therefore, it is an object of the present disclosure to provide a magnetic recording device, a laminated structure, and a spacer with improvements regarding impact resistance and fluttering properties.

Solution to Problem

[0006] The inventor of the present invention found that, by using a substrate and a spacer that satisfy a predetermined relationship in combination, even when a thin substrate is used, deformation of the substrate that may be caused by changes in temperature of a usage environment is prevented and an improvement in the impact resistance and the fluttering properties is achieved.

[0007] An embodiment of the present disclosure relates to a magnetic recording device including:

a plurality of magnetic disks that each include a substrate having a thickness of 0.51 mm or less and a magnetic recording layer formed on the substrate; and

a spacer that is disposed between the plurality of magnetic disks and is used to layer the magnetic disks at a predetermined interval,

wherein the substrate and the spacer satisfy an expression (1):

$$[\text{CTE}(\text{sub}) \cdot \text{E}(\text{spa})] / [\text{CTE}(\text{spa}) \cdot \text{E}(\text{sub})] < 1.0 \cdots (1)$$

(where

CTE(sub) is a coefficient of thermal expansion ($\times 10^{-7}/\text{K}$) of the substrate at 100°C to 300°C,

CTE(spa) is a coefficient of thermal expansion ($\times 10^{-7}/\text{K}$) of the spacer at 100°C to 300°C,

E(sub) is a Young's modulus (GPa) of the substrate, and

E(spa) is a Young's modulus (GPa) of the spacer).

[0008] An embodiment of the present disclosure relates to a laminated structure including:

a plurality of magnetic disks that each include a substrate having a thickness of 0.51 mm or less and a magnetic recording layer formed on the substrate; and

a spacer that is disposed between the plurality of magnetic disks and is used to layer the

magnetic disks at a predetermined interval,

wherein the substrate and the spacer satisfy an expression (1):

$$[\text{CTE}(\text{sub}) \cdot \text{E}(\text{spa})] / [\text{CTE}(\text{spa}) \cdot \text{E}(\text{sub})] < 1.0 \cdots (1)$$

(where

5 CTE(sub) is a coefficient of thermal expansion ($\times 10^{-7}/\text{K}$) of the substrate at 100°C to 300°C,

CTE(spa) is a coefficient of thermal expansion ($\times 10^{-7}/\text{K}$) of the spacer at 100°C to 300°C,

E(sub) is a Young's modulus (GPa) of the substrate, and

10 E(spa) is a Young's modulus (GPa) of the spacer).

Advantageous Effects of Invention

[0009] With the present embodiment, it is possible to provide a magnetic recording device, a laminated structure, and a spacer in which deformation of the substrate caused by changes in temperature of a usage environment is less likely to occur.

15 Brief Description of Drawings

[0010] [FIG. 1] FIG. 1 shows a schematic configuration diagram of a magnetic recording device according to the present embodiment.

[FIG. 2] FIG. 2 is a schematic cross-sectional view of a laminated structure.

[FIG. 3] FIG. 3 is a conceptual diagram illustrating a layer structure.

20 [FIG. 4] FIG. 4 is a perspective view illustrating the external appearance of a magnetic disk according to the present embodiment.

[FIG. 5] FIG. 5 is a cross-sectional view of the magnetic disk according to the present embodiment.

25 [FIG. 6] FIG. 6 is a perspective view illustrating the external appearance of a spacer according to the present embodiment.

Description of Embodiments

[0011] Preferred embodiments of the present disclosure will be described with reference to the attached drawings (note that in the drawings, components denoted by the same reference numeral have the same or similar configuration). The following embodiments are merely examples for
30 facilitating the understanding of the present disclosure, and are not to be construed as limiting

the present disclosure. Elements included in the embodiments, and their arrangement, materials, conditions, shapes, sizes, and the like are not limited to those described as examples, and can be changed as appropriate. In addition, the configurations described in different embodiments can be partially exchanged or combined.

5 [0012] [Magnetic Recording Device]

A magnetic recording device according to the present embodiment includes:

a plurality of magnetic disks that each include a substrate having a thickness of 0.51 mm or less and a magnetic recording layer formed on the substrate; and

10 a spacer that is disposed between the plurality of magnetic disks and is used to layer the magnetic disks at a predetermined interval.

Also, in the magnetic recording device according to the present embodiment, the substrate and the spacer satisfy an expression (1):

$$[\text{CTE}(\text{sub}) \cdot \text{E}(\text{spa})] / [\text{CTE}(\text{spa}) \cdot \text{E}(\text{sub})] < 1.0 \cdots (1)$$

(where

15 CTE(sub) is a coefficient of thermal expansion ($\times 10^{-7}/\text{K}$) of the substrate at 100°C to 300°C,

CTE(spa) is a coefficient of thermal expansion ($\times 10^{-7}/\text{K}$) of the spacer at 100°C to 300°C,

E(sub) is a Young's modulus (GPa) of the substrate, and

20 E(spa) is a Young's modulus (GPa) of the spacer).

With the above configuration, a magnetic recording device with improvements regarding the impact resistance and the fluttering properties is obtained.

[0013] In the magnetic recording device according to the present embodiment, the substrate and the spacer that satisfy the expression (1): $[\text{CTE}(\text{sub}) \cdot \text{E}(\text{spa})] / [\text{CTE}(\text{spa}) \cdot \text{E}(\text{sub})] < 1.0$ are used
 25 in combination, and thus, when the plurality of magnetic disks and the spacer are layered and used, deformation of the substrate is less likely to occur even when the magnetic recording device is used in a high-temperature environment. Conventionally, it has been considered that using the same material for the spacer and a glass substrate makes it possible to allow them to have the same coefficient of thermal expansion and thus prevent breakage caused by changes in
 30 temperature. However, it was found that the deformation of the substrate is even less likely to

occur when the value of $[\text{CTE}(\text{sub}) \cdot \text{E}(\text{spa})] / [\text{CTE}(\text{spa}) \cdot \text{E}(\text{sub})]$ is less than 1.0 than when that value is 1.0.

[0014] It was also found that the impact resistance of the magnetic recording device is improved when the expression (1) is satisfied. In order to increase the storage capacity of the magnetic recording device or reduce the size of the device, it is envisaged that the thickness of the substrate is reduced to enable layering of more magnetic disks, or the size of the magnetic disk is reduced even when the same number of magnetic disks are layered. However, when the substrate is thin, a problem arises in that breakage due to drop impact is likely to occur. When the above expression (1) is satisfied, this problem is also solved.

[0015] It is preferable that the substrate and the spacer in the magnetic recording device according to the present embodiment satisfy an expression (2): $0.30 \leq [\text{CTE}(\text{sub}) \cdot \text{E}(\text{spa})] / [\text{CTE}(\text{spa}) \cdot \text{E}(\text{sub})] \cdots (2)$.

[0016] The value of $[\text{CTE}(\text{sub}) \cdot \text{E}(\text{spa})] / [\text{CTE}(\text{spa}) \cdot \text{E}(\text{sub})]$ is less than 1.0, preferably within a range of 0.30 to 0.98, more preferably within a range of 0.35 to 0.95, even more preferably within a range of 0.56 to 0.95, even more preferably within a range of 0.80 to 0.95, and even more preferably within a range of 0.82 to 0.92. When this value is within the above range, the deformation of the substrate caused by changes in temperature of the usage environment is less likely to occur. In addition, the impact resistance is further improved, and occurrence of fluttering is prevented.

[0017] It is preferable that the spacer satisfies an expression (3): $\text{CTE}(\text{spa}) \cdot \text{E}(\text{spa}) \leq 1.0 \times 10^4 \cdots (3)$. When the expression (3) is satisfied, a further improvement in the impact resistance and the fluttering properties of the magnetic recording device is achieved.

$\text{CTE}(\text{spa}) \cdot \text{E}(\text{spa})$ is preferably 0.8×10^4 or less, more preferably within a range of 0.1×10^4 to 0.7×10^4 , and even more preferably within a range of 0.2×10^4 to 0.4×10^4 .

[0018] It is preferable that the substrate satisfies an expression (4): $\text{CTE}(\text{sub}) \cdot \text{E}(\text{sub}) \leq 0.5 \times 10^4 \cdots (4)$. When the expression (4) is satisfied, a further improvement in the impact resistance and the fluttering properties of the magnetic recording device is achieved.

$\text{CTE}(\text{sub}) \cdot \text{E}(\text{sub})$ is preferably 0.45×10^4 or less, more preferably within a range of 0.10×10^4 to 0.40×10^4 , and even more preferably within a range of 0.20×10^4 to 0.35×10^4 .

[0019] It is preferable that the substrate satisfies an expression (5): $\text{CTE}(\text{sub}) / \text{E}(\text{sub}) \leq 1.5 \cdots (5)$.

When the expression (4) is satisfied, it is possible to suppress the fluttering properties to a low level in a usage environment of the magnetic recording device even when the substrate has a thickness of 0.51 mm or less in the magnetic recording device.

The value of $\text{CTE}(\text{sub}) / E(\text{sub})$ is 1.5 or less, preferably 0.8 or less, and even more preferably within a range of 0.35 to 0.5.

[0020] It is preferable that the substrate and the spacer satisfy an expression (6): $[\text{CTE}(\text{spa}) \cdot E(\text{spa})] / [\text{CTE}(\text{sub}) \cdot E(\text{sub})] < 1 \cdots (6)$. When the expression (6) is satisfied, the magnetic recording device satisfies the expression (1) as well as the expression (6), and thus a further improvement in the impact resistance and the fluttering properties is achieved.

The value of $[\text{CTE}(\text{spa}) \cdot E(\text{spa})] / [\text{CTE}(\text{sub}) \cdot E(\text{sub})]$ is less than 1, preferably 0.98 or less, more preferably 0.95 or less, and even more preferably within a range of 0.30 to 0.90.

[0021] $\text{CTE}(\text{sub})$ is the coefficient of thermal expansion ($\times 10^{-7}/\text{K}$) of the substrate at 100°C to 300°C. The amount of a change in the length of a sample cut out in a size having a length of 50 mm and a width of 10 mm is determined within a predetermined temperature range using a thermal dilatometer based on the laser interferometry, and is taken as the value of a mean coefficient of linear expansion at 100°C to 300°C. Note that an influence of a magnetic film included in the magnetic disk on the coefficient of thermal expansion is negligible, and therefore, the coefficient of thermal expansion of the magnetic disk may be taken as the coefficient of thermal expansion of the substrate. The measurement method will be more specifically described in the Examples section.

[0022] $\text{CTE}(\text{spa})$ is the coefficient of thermal expansion ($\times 10^{-7}/\text{K}$) of the spacer at 100°C to 300°C. When a sample having the same size as that of the sample of the substrate cannot be cut out for the measurement of the coefficient of thermal expansion of the spacer, the spacer is pulverized after a conductive film on the outer surface is removed, the pulverized sample is washed, dried, and then remelted at a predetermined temperature, and a sample having the same size as that of the sample of the substrate is prepared and subjected to the measurement.

[0023] $E(\text{sub})$ is the Young's modulus (GPa) of the substrate. The Young's modulus can be measured based on JIS R1602:1995. A measurement test piece having a rectangular parallelepiped shape having a length of 50 mm, a width of 10 mm, and the same thickness as the thickness of the magnetic disk is cut out from the magnetic disk, and can be subjected to the

measurement at ordinary temperature. Note that an influence of a magnetic film included in the magnetic disk on the coefficient of thermal expansion is negligible, and therefore, the coefficient of thermal expansion of the magnetic disk may be taken as the coefficient of thermal expansion of the substrate.

5 [0024] $E(\text{spa})$ is the Young's modulus (GPa) of the spacer. The Young's modulus can be measured based on JIS R1602:1995. A test piece for the measurement of the spacer is cut out, in a rectangular parallelepiped shape having the same thickness as the thickness of the magnetic disk, from a sample prepared by pulverizing the spacer after removing the conductive film on the outer surface from the spacer, washing and drying the pulverized sample, and then remelting it
10 at a predetermined temperature, and is then subjected to the measurement at ordinary temperature. [0025] Hereinafter, the magnetic recording device according to the present embodiment will be described in detail.

FIG. 1 shows a schematic configuration diagram of the magnetic recording device according to the present embodiment. A magnetic recording device 1 has a laminated structure
15 2 that includes a plurality of magnetic disks 21. In the magnetic recording device 1 according to the embodiment, the laminated structure 2 is attached to a spindle motor (not illustrated). The spindle motor rotates the magnetic disks 21 of the laminated structure 2.

[0026] A head assembly 3 includes a head slider 31. The head assembly 3 includes a plurality of the head sliders 31 aligned in the vertical direction. Each of the head sliders 31 includes a
20 magnetic head near its tip end. The head slider 31 conducts recording and reproduction of information on the rotating magnetic disk 21. Providing the plurality of head sliders 31 aligned in the vertical direction makes it possible to read the information from the magnetic disks 21 layered at a predetermined interval. In this case, with magnetic disks 21 in which deformation of the substrate caused by changes in temperature of a usage environment is less likely to occur
25 or that have improved impact resistance, interference of the head sliders or the magnetic heads with the magnetic disks is less likely to occur during the recording or reading of the information.

[0027] FIG. 2 is a schematic cross-sectional view of the laminated structure. The laminated structure 2 includes the plurality of magnetic disks 21, and a spacer 22 that is disposed between the plurality of magnetic disks 21 and is used to layer the magnetic disks 21 at a predetermined
30 interval. FIG. 2 illustrates an example in which the laminated structure 2 includes three

magnetic disks 21, but the number of the magnetic disks 21 is not particularly limited.

[0028] As shown in FIG. 2, the plurality of magnetic disks 21 are inserted into a rotatable spindle 23 with the spacer 22 provided between the magnetic disks 21 and are fixed to the spindle 23 by being pressed, from above the laminated structure 2 that includes the magnetic disks 21 and the spacer 22, by a clamp member 24 fixed with a screw or the like, and thus the magnetic disks 21 are attached at a predetermined interval. The clamp member 24 presses the uppermost magnetic disk 21. The entire laminate is also pressed by the pressing force and is thus fixed. The clamp member 24 is provided with a circular protrusion 241 for pressing the magnetic disk 21, about the central axis of the spindle 23.

[0029] As shown in FIG. 3, the laminated structure is formed by alternately layering the magnetic disks 21 and the spacers 22, and is incorporated into a magnetic storage device.

[0030] FIG. 4 is a perspective view illustrating the external appearance of the magnetic disk 21 according to the present embodiment. The magnetic disk 21 has an annular shape and is provided with a spindle hole 215. The magnetic disk 21 includes main surfaces 216 opposed to each other. The pair of main surfaces are substantially parallel to each other. The wording "substantially parallel" as used herein means that, for example, the degree of parallelism is 5 μ m or less.

[0031] FIG. 5 is a cross-sectional view of the magnetic disk 21 according to the present embodiment. The magnetic disk 21 includes a substrate 211 having a thickness of 0.51 mm or less and magnetic recording layers 213.

[0032] It is preferable that the substrate has a thickness of 0.51 mm or less. The thickness of the substrate is preferably 0.50 mm or less, more preferably 0.30 to 0.50 mm, and even more preferably 0.32 to 0.45 mm.

[0033] Examples of the material of the substrate include metal materials such as stainless steel, titanium, aluminum, and aluminum alloys, ceramics, and glass. Out of substrates made of these materials, a glass substrate is preferable.

[0034] The glass composition of the glass substrate preferably contains

SiO₂ in an amount of 55 mol% to 80 mol%, Al₂O₃ in an amount of 5 mol% to 25 mol%, B₂O₃ in an amount of 0 mol% to 8 mol%, P₂O₅ in an amount of 0 mol% to 5 mol%, MO in an amount of 5 mol% to 25 mol% (MO is at least one selected from MgO, CaO, SrO, and BaO, and

the content thereof is the sum of the contents of MgO, CaO, SrO, and BaO), and M₂O in an amount of 0 mol% to 15 mol% (M₂O is at least one selected from Li₂O, Na₂O, and K₂O, and the content thereof is the sum of the contents of Li₂O, Na₂O, and K₂O). The glass composition of the glass substrate may be composed of these components.

5 [0035] Preferable contents of the components in the glass composition of the glass substrate are as follows.

[0036] SiO₂ is a glass network-forming component. The content of SiO₂ is preferably 55 mol% to 80 mol%, more preferably 57 mol% to 75 mol%, and even more preferably 60 mol% to 70 mol% from the viewpoint of improving the stability of the glass and improving the meltability
10 during the production.

[0037] The content of Al₂O₃ is preferably 5 mol% to 25 mol%, more preferably 10 mol% to 20 mol%, and even more preferably 12 mol% to 18 mol% from the viewpoint of improving the thermal resistance of the glass and improving the stability of the glass.

[0038] B₂O₃ is a glass network-forming component. The content of B₂O₃ is preferably 0
15 mol% to 8 mol%, more preferably 0.1 mol% to 5 mol%, and even more preferably 0.1 mol% to 3 mol%.

[0039] The content of P₂O₅ is preferably 0 mol% to 5 mol%, more preferably 0 mol% to 3 mol%, and even more preferably 0 mol% to 2 mol%.

[0040] MO is at least one selected from MgO, CaO, SrO, and BaO, and the content thereof is
20 the sum of the contents of MgO, CaO, SrO, and BaO. The content of MO is preferably 5 mol% to 25 mol%, more preferably 6 mol% to 20 mol%, and even more preferably 14 mol% to 18 mol% from the viewpoint of adjusting the Young's modulus.

The content of MgO is preferably 3 mol% to 20 mol%, more preferably 4 mol% to 19 mol%, and even more preferably 8 mol% to 18 mol% from the viewpoint of adjusting the Young's
25 modulus.

[0041] The content of CaO is preferably 0 mol% to 10 mol%, more preferably 0 mol% to 8 mol%, and even more preferably 0 mol% to 6 mol% from the viewpoint of improving the productivity.

[0042] The content of SrO is preferably 0 mol% to 5 mol%, more preferably 0 mol% to 3 mol%,
30 and even more preferably 0 mol% to 1.5 mol% from the viewpoint of reducing the specific

gravity of the glass.

[0043] The content of BaO is preferably 0 mol% to 5 mol%, more preferably 0 mol% to 4 mol%, and even more preferably 0 mol% to 1.5 mol% from the viewpoint of reducing the specific gravity of the glass.

5 [0044] M_2O is at least one selected from Li_2O , Na_2O , and K_2O , and the content thereof is the sum of the contents of Li_2O , Na_2O , K_2O . The content of M_2O is preferably 0 mol% to 15 mol%, more preferably 0 mol% to 10 mol%, and even more preferably 0.5 mol% to 9 mol%.

[0045] The content of Li_2O is preferably 0 mol% to 5 mol%, more preferably 0 mol% to 7 mol%, and even more preferably 0.5 mol% to 6 mol% from the viewpoint of improving the
10 thermal resistance.

[0046] The content of Na_2O is preferably 0 mol% to 10 mol%, more preferably 0 mol% to 7 mol%, and even more preferably 0.5 mol% to 5 mol%.

[0047] The content of K_2O is preferably 0 mol% to 3 mol%, more preferably 0 mol% to 1 mol%, and even more preferably 0 mol% to 0.3 mol%.

15 [0048] It is preferable that the substrate is a glass substrate,
the glass substrate satisfies the expression (5): $CTE(sub) / E(sub) \leq 1.5 \cdots (5)$, and
the glass composition of the glass substrate contains

SiO_2 in an amount of 55 mol% to 80 mol%, Al_2O_3 in an amount of 5 mol% to 25 mol%, B_2O_3 in an amount of 0 mol% to 8 mol%, MO in an amount of 5 mol% to 25 mol%
20 (MO is at least one selected from MgO, CaO, SrO, and BaO, and the content thereof is the sum of the contents of MgO, CaO, SrO, and BaO), and M_2O in an amount of 0 mol% to 15 mol% (M_2O is at least one selected from Li_2O , Na_2O , and K_2O , and the content thereof is the sum of the contents of Li_2O , Na_2O , and K_2O).

[0049] For example, the following SU-1, SU-2, and SU-3 are shown as examples of the glass
25 composition of the glass substrate.

[0050] SU-1: Alkali-free glass containing SiO_2 in an amount of 60 mol% to 70 mol%, Al_2O_3 in an amount of 8 mol% to 15 mol%, B_2O_3 in an amount of 1 mol% to 5 mol%, MO in an amount of 10 mol% to 20 mol% (MO is at least one selected from MgO, CaO, SrO, and BaO, and the content thereof is the sum of the contents of MgO, CaO, SrO, and BaO), and M_2O in an amount
30 of 0 mol% to 1 mol% (M_2O is at least one selected from Li_2O , Na_2O , and K_2O , and the content

thereof is the sum of the contents of Li_2O , Na_2O , and K_2O)

[0051] SU-2: Alkali-free glass containing SiO_2 in an amount of 60 mol% to 70 mol%, Al_2O_3 in an amount of 8 mol% to 15 mol%, B_2O_3 in an amount of 1 mol% to 5 mol%, MO in an amount of 10 mol% to 20 mol% (MO is at least one selected from MgO , CaO , SrO , and BaO , and the content thereof is the sum of the contents of MgO , CaO , SrO , and BaO), and M_2O in an amount of 0 mol% to 1 mol% (M_2O is at least one selected from Li_2O , Na_2O , and K_2O , and the content thereof is the sum of the contents of Li_2O , Na_2O , and K_2O)

[0052] SU-3: Alkali-containing glass containing SiO_2 in an amount of 55 mol% to 75 mol%, Al_2O_3 in an amount of 5 mol% to 20 mol%, B_2O_3 in an amount of 0 mol% to 3 mol%, MO in an amount of 12 mol% to 25 mol% (MO is at least one selected from MgO , CaO , SrO , and BaO , and the content thereof is the sum of the contents of MgO , CaO , SrO , and BaO), and M_2O in an amount of 0.1 mol% to 10 mol% (M_2O is at least one selected from Li_2O , Na_2O , and K_2O , and the content thereof is the sum of the contents of Li_2O , Na_2O , and K_2O)

[0053] In the present disclosure, the glass composition is represented as a glass composition on the oxide basis. The wording "glass composition on the oxide basis" as used herein means a glass composition obtained through conversion based on the assumption that the glass raw materials are all decomposed during melting and are present in the form of an oxide in the glass.

The glass composition in the present disclosure can be determined using a method such as ICP-AES (Inductively Coupled Plasma-Atomic Emission Spectrometry). Quantitative analysis is conducted for each element using the ICP-AES. Thereafter, the analysis values are converted to values on the oxide basis. An analysis value obtained through the ICP-AES may include a measurement error of about $\pm 5\%$ of the analysis value. Therefore, a value converted on the oxide basis from the analysis value may also include a measurement error of about $\pm 5\%$.

Also, in the present disclosure, the wording "the content of a constituent component is 0 mol%" means that this constituent component is not substantially contained, and refers to a situation where the content of this constituent component is lower than or equal to an extent of the impurity level. The wording "lower than or equal to an extent of the impurity level" means that the content is, for example, lower than 0.01 mol%.

[0054] The coefficient of thermal expansion of the substrate, $\text{CTE}(\text{sub})$ (unit: $\times 10^{-7}/\text{K}$), at 100°C to 300°C is preferably 10 to 110, more preferably 25 to 98, and even more preferably 30

to 55.

[0055] The Young's modulus of the substrate, $E(\text{sub})$ (unit: GPa), is preferably 75 to 120, more preferably 80 to 110, and even more preferably 85 to 105.

[0056] The value of the specific elastic modulus E/d of the substrate is preferably 32.0×10^6 m^2/s^2 or more, more preferably 33.5×10^6 m^2/s^2 or more, and preferably 35.0×10^6 m^2/s^2 or more.

When the substrate has a specific elastic modulus E/d within this range, the impact resistance is further improved. When a substrate having a thickness of 0.51 mm or less has the value of the specific elastic modulus E/d within the above range, the above effects are more remarkably obtained. The wording "specific elastic modulus E/d " means a value obtained by dividing the

Young's modulus by the specific gravity.

[0057] The magnetic disk 21 includes the magnetic recording layers 213. The magnetic disk 21 may include, for example, an adherent layer, a base layer, a magnetic recording layer (magnetic layer), a protective layer, and a lubricating layer that are layered in this order from the main surface side, on the main surface of a glass substrate polished into a smooth surface.

Out of these layers, the adherent layer, the base layer, and the magnetic recording layer are, for example, successively formed on the main surface of a glass substrate introduced into a film formation device that has been evacuated, through a DC (Direct Current) magnetron sputtering method in an Ar atmosphere. The adherent layer can be formed using, for example, CrTi, and the base layer can be formed using, for example, materials that include Ru and MgO.

Note that a soft magnetic layer and a heat sink layer may be added as appropriate. After the above-mentioned film formation, it is possible to form the protective layer through, for example, a CVD (Chemical Vapor Deposition) method using C_2H_4 , and form the lubricating layer by conducting nitriding for introducing nitrogen into the surface in the same chamber and then applying, for example, PFPE (polyfluoropolyether) onto the protective layer through a dip coat method. The magnetic disk 21 can be produced in this manner.

[0058] In order to achieve higher density recording of the magnetic disk 21, it is preferable that the magnetic recording layer includes a magnetic material with high magnetic anisotropic energy. A magnetic material that is preferred from this viewpoint may be, for example, a Fe-Pt-based magnetic material or a Co-Pt-based magnetic material. Note that the term "-based" as used herein means "-containing".

[0059] That is to say, it is preferable that the magnetic disk 21 includes a magnetic recording layer containing Fe and Pt, or Co and Pt. Regarding the magnetic recording layer containing such a magnetic material and a method for forming the magnetic recording layer, WO 2011/019010 can be referred to. In addition, it is preferable that the magnetic disk 21 having such a magnetic recording layer is applied to a magnetic recording device based on a recording system called energy-assisted magnetic recording (EAMR). Among the types of energy-assisted magnetic recording, a recording system in which irradiation with near-field light or the like assists magnetization reversal is called heat-assisted magnetic recording (HAMR), and a recording system assisted by microwave is called microwave-assisted magnetic recording (MAMR). Regarding the details thereof, WO 2011/019010 can be referred to. Note that CoPtCr-based materials may be used as a magnetic material for forming the magnetic recording layer.

[0060] FIG. 6 is a perspective view illustrating the external appearance of the spacer 22 according to the present embodiment. The spacer 22 has an annular shape and is provided with a spindle hole 225. The spacer 22 includes main surfaces 226 opposed to each other. The pair of main surfaces are substantially parallel to each other. The wording "substantially parallel" as used herein means that, for example, the degree of parallelism is 5 μm or less.

[0061] Examples of the material of the spacer include metal materials such as stainless steel, titanium, aluminum, and aluminum alloys, ceramics, and glass. Out of spacers made of these materials, the spacer is preferably a spacer made of at least one material selected from the group consisting of glass, stainless steel, and titanium, and more preferably a glass spacer.

[0062] The glass composition of the spacer preferably contains

SiO₂ in an amount of 55 mol% to 88 mol%, Al₂O₃ in an amount of 0 mol% to 20 mol%, B₂O₃ in an amount of 1 mol% to 30 mol%, P₂O₅ in an amount of 0 mol% to 5 mol%, MO in an amount of 0 mol% to 20 mol% (MO is at least one selected from MgO, CaO, SrO, and BaO, and the content thereof is the sum of the contents of MgO, CaO, SrO, and BaO), and M₂O in an amount of 0 mol% to 15 mol% (M₂O is at least one selected from Li₂O, Na₂O, and K₂O, and the content thereof is the sum of the contents of Li₂O, Na₂O, and K₂O).

The glass composition of the glass substrate may be composed of these components.

Note that it is preferable that the glass composition of the spacer is different from the glass

composition of the substrate.

[0063] Preferable contents of the components in the glass composition of the spacer are as follows.

[0064] SiO_2 is a glass network-forming component. The content of SiO_2 is preferably 55 mol% to 88 mol%, more preferably 65 mol% to 85 mol%, and even more preferably 75 mol% to 85 mol% from the viewpoint of improving the stability of the glass and improving the meltability during the production.

[0065] The content of Al_2O_3 is preferably 0 mol% to 20 mol%, more preferably 1 mol% to 17 mol%, and even more preferably 1 mol% to 5 mol% from the viewpoint of improving the thermal resistance of the glass and improving the stability of the glass.

[0066] B_2O_3 is a glass network-forming component. The content of B_2O_3 is preferably 1 mol% to 30 mol%, more preferably 5 mol% to 28 mol%, even more preferably 8 mol% to 28 mol%, and even more preferably 10 mol% to 20 mol%.

[0067] The content of P_2O_5 is preferably 0 mol% to 5 mol%, more preferably 0 mol% to 3 mol%, and even more preferably 0 mol% to 2 mol%.

[0068] MO is at least one selected from MgO, CaO, SrO, and BaO, and the content thereof is the sum of the contents of MgO, CaO, SrO, and BaO. The content of MO is preferably 0 mol% to 20 mol%, more preferably 0 mol% to 5 mol%, and even more preferably 0 mol% from the viewpoint of adjusting the Young's modulus.

The content of MgO is preferably 0 mol% to 10 mol%, more preferably 0 mol% to 5 mol%, and even more preferably 0 mol% from the viewpoint of adjusting the Young's modulus.

[0069] The content of CaO is preferably 0 mol% to 10 mol%, more preferably 0 mol% to 5 mol%, and even more preferably 0 mol% from the viewpoint of improving the productivity.

[0070] The content of SrO is preferably 0 mol% to 4 mol%, more preferably 0 mol% to 3 mol%, and even more preferably 0 mol% from the viewpoint of reducing the specific gravity of the glass.

[0071] The content of BaO is preferably 0 mol% to 5 mol%, more preferably 0 mol% to 3 mol%, and even more preferably 0 mol% from the viewpoint of reducing the specific gravity of the glass.

[0072] M_2O is at least one selected from Li_2O , Na_2O , and K_2O , and the content thereof is the sum of the contents of Li_2O , Na_2O , K_2O . The content of M_2O is preferably 0 mol% to 15 mol%, more preferably 0 mol% to 10 mol%, and even more preferably 0.1 mol% to 8 mol%.

[0073] The content of Li_2O is preferably 0 mol% to 4 mol%, more preferably 0 mol% to 3 mol%, and even more preferably 0 mol% to 2 mol% from the viewpoint of improving the thermal resistance.

[0074] The content of Na_2O is preferably 0 mol% to 15 mol%, more preferably 0.1 mol% to 10 mol%, and even more preferably 1 mol% to 5 mol%.

[0075] The content of K_2O is preferably 0 mol% to 3 mol%, more preferably 0 mol% to 2 mol%, and even more preferably 0.1 mol% to 0.5 mol%.

[0076] It is preferable that the spacer is a glass substrate,
the glass substrate satisfies the expression (5): $\text{CTE}(\text{sub}) / \text{E}(\text{sub}) \leq 1.5 \cdots (5)$, and
the glass composition of the spacer contains

SiO_2 in an amount of 55 mol% to 88 mol%, Al_2O_3 in an amount of 0 mol% to 20 mol%, B_2O_3 in an amount of 1 mol% to 30 mol%, MO in an amount of 0 mol% to 20 mol% (MO is at least one selected from MgO, CaO, SrO, and BaO, and the content thereof is the sum of the contents of MgO, CaO, SrO, and BaO), and M_2O in an amount of 0 mol% to 15 mol% (M_2O is at least one selected from Li_2O , Na_2O , and K_2O , and the content thereof is the sum of the contents of Li_2O , Na_2O , and K_2O), the glass composition of the spacer being different from the glass composition of the substrate of the magnetic disk.

[0077] For example, the following SP-1 is shown as an example of the glass composition of the spacer.

[0078] SP-1: Borosilicate glass containing SiO_2 in an amount of 78 mol% to 88 mol%, Al_2O_3 in an amount of 1 mol% to 5 mol%, B_2O_3 in an amount of 10 mol% to 28 mol%, MO in an amount of 3 mol% to 8 mol% (MO is at least one selected from MgO, CaO, SrO, and BaO, and the content thereof is the sum of the contents of MgO, CaO, SrO, and BaO), and M_2O in an amount of 0 mol% to 5 mol% (M_2O is at least one selected from Li_2O , Na_2O , and K_2O , and the content thereof is the sum of the contents of Li_2O , Na_2O , and K_2O)

[0079] It is preferable that the spacer includes a spacer substrate made of glass, and a conductive film on the outer surface of the spacer substrate. The conductive film may be made of a conductive oxide such as SnO_2 (tin oxide), ZnO, In_2O_3 , or ITO (indium tin oxide), or the like. Note that the conductive film may be made of the above conductive oxide doped with fluorine.

Also, the conductive film may be a metallic film. Examples of the component of the metallic

film include chromium, titanium, tantalum, tungsten, and alloys containing these metals, and nickel alloys such as NiP (nickel phosphorus) and NiW (nickel tungsten). The nickel alloys are preferably non-magnetic. The conductive film is formed using a dipping method to be used for plating such as electroless plating, a deposition method, a sputtering method, or the like.

5 [0080] The coefficient of thermal expansion of the spacer, CTE(spa) (unit: $\times 10^{-7}/K$), at 100°C to 300°C is preferably 10 to 105, more preferably 25 to 95, and even more preferably 30 to 45.

[0081] The Young's modulus of the spacer, E(spa) (unit: GPa), is preferably 30 to 120, more preferably 50 to 80, and even more preferably 50 to 75.

[0082] Preferred examples of a combination of the glass substrate and the spacer include SU-1
10 and SP-1, SU-2 and SP-1, and SU-3 and SP-1. With the above combinations, an improvement in the impact resistance and the fluttering properties is achieved.

[0083] Examples of the material of the spindle include aluminum and stainless steel. Out of these materials, aluminum is preferable from the viewpoint of reducing the weight. It is preferable that the magnetic disks 21 and the spacer 22 are fixed to the spindle made of aluminum
15 or stainless steel. A spindle made of aluminum is lightweight as described above but tends to have a high coefficient of thermal expansion and a low Young's modulus. However, with the combination of the magnetic disks and the spacer according to the present embodiment, deformation of the substrate caused by changes in temperature of a usage environment is less likely to occur.

20 [0084] It is preferable that when impact is applied to each of the magnetic disks installed in the magnetic recording device under conditions of 2 [msec] and 40 [G] in a normal direction of the main surfaces of the magnetic disk, the maximum amplitude of vibration in a thickness direction of the outer circumferential end portion of the magnetic disk is 0.25 mm or less. The maximum amplitude is preferably 0.23 mm or less and more preferably 0.18 mm or less. When the
25 maximum amplitude is within this range, it is possible to prevent generation of particles resulting from chipping of the magnetic disk even when the magnetic disk comes into contact with another magnetic disk or another member due to vibration caused by impact from the outside. Note that the above impact test is conducted using an AVEX-SM-110-MP-type tester available from AR BROWN Co., Ltd.

30 [0085] As described above, with the present embodiment, it is possible to provide a magnetic

recording device, a laminated structure, and a spacer with improvements regarding the impact resistance and the fluttering properties.

Examples

[0086] Hereinafter, the present embodiment will be more specifically described using examples, but the present embodiment is not limited to the examples below.

[0087] <Coefficient of Thermal Expansion>

Regarding the coefficient of thermal expansion of the substrate, the amount of a change in the length of a sample cut out in a size having a length of 50 mm and a width of 10 mm from the magnetic disk was determined within a predetermined temperature range using a thermal dilatometer based on the laser interferometry, and was taken as the value of a mean coefficient of linear expansion at 100°C to 300°C.

Note that a sample having the same size as that of the sample of the magnetic disk could not be cut out for the measurement of the coefficient of thermal expansion of the spacer. Therefore, the spacer was heated and melted, and was then poured into a flat mold and annealed to ordinary temperature at a rate of 50°C / 10 min. Thus, a glass plate having a thickness of 0.5 mm was obtained. Thereafter, the measurement could be conducted using a sample cut out in a size having a length of 50 mm and a width of 10 mm. Note that a sample can be produced using a plurality of spacers if the spacers have the same composition.

[0088] <Young's Modulus>

The Young's modulus E of the substrate was measured based on JIS R1602:1995. A measurement test piece having a rectangular parallelepiped shape having a length of 50 mm, a width of 10 mm, and the same thickness as the thickness of the magnetic disk was cut out from the magnetic disk, and was subjected to the measurement at ordinary temperature.

Note that a sample having the same size as that of the sample of the magnetic disk could not be cut out for the measurement of the Young's modulus of the spacer. Therefore, the spacer was heated and melted, and was then poured into a flat mold and annealed to ordinary temperature at a rate of 50°C / 10 min. Thus, a glass plate having a thickness of 0.5 mm was obtained. Thereafter, the measurement could be conducted using a sample cut out in a size having a length of 50 mm and a width of 10 mm. Note that a sample can be produced using a plurality of spacers if the spacers have the same composition.

[0089] <Density>

The density was measured using the Archimedes method.

[0090] An influence of the magnetic film on the coefficient of thermal expansion, the Young's modulus, and the density of the magnetic disk is negligible, and therefore, the values obtained from the magnetic disk can be taken as the coefficient of thermal expansion, the Young's modulus, and the density of the substrate.

[0091] <Impact Test: Maximum Amplitude>

The impact test was conducted using an AVEX-SM-110-MP-type tester available from AR BROWN Co., Ltd.

Impact was applied to each of the magnetic disks installed in the magnetic recording device under conditions of 2 [msec] and 40 [G] in a normal direction of main surfaces of the magnetic disk. The maximum amplitude of vibration in a thickness direction of the outer circumferential end portion of the magnetic disk was recorded, and the impact properties were evaluated.

[0092] <Fluttering Properties>

A laser Doppler vibrometer (OFV-512 manufactured by Polytec GmbH) was used to vibrate the magnetic disk rotated using a spin stand, the vibration was measured by irradiating a portion located at substantially the outer circumferential end of this magnetic disk with a laser beam, and a frequency response function (the horizontal axis represents the frequency (unit: Hz), and the vertical axis represents the NRRO (Non Repeatable Runout) amplitude (unit: nm)) was obtained by conducting Fourier transformation on the obtained data as appropriate. Next, a half-power band width method (a method for calculating a Q-value using frequencies f_1 and f_2 ($> f_1$) corresponding to a value that is 3 dB smaller than the peak value of NRRO and a frequency f_0 (resonance frequency) corresponding to the peak value) was used to determine a Q-value ($= f_0 / (f_2 - f_1)$) for each peak observed in the frequency response function. The obtained measurement results were plotted in an XY plane with the horizontal axis representing the frequency and the vertical axis representing the Q-value, and an approximate straight line was determined by conducting linear approximation based on the least squares method. A Q-value under the condition of 3000 Hz was obtained from the determined approximate straight line or by extrapolating the approximate straight line as needed. The sum total RSS of the NRRO

amplitudes (nm) from 1000 to 4000 Hz, which is the flutter vibration amount of the disk, measured using the laser Doppler vibrometer was calculated and was taken as the fluttering value F [nm]. For the evaluation using the laser Doppler vibrometer, the measurement was conducted under the following conditions: the number of revolutions of the magnetic disk was 6900 rpm, the measurement position was located 46.5 mm away from the center of the magnetic disk in the radial direction (a position that is 1 mm inside from the outer circumferential end), and the temperature was room temperature (25°C).

Note that the fluttering properties were evaluated using the $F \cdot D$ value. D is the thickness (mm) of the magnetic disk.

10 [0093] (Examples and Comparative Examples)

In Example 1, a magnetic recording device in which a laminate formed by layering ten magnetic disks described below with spacers described below being provided between the magnetic disks had been installed was used to measure the maximum amplitude and the fluttering properties. Note that in the other examples and comparative examples, magnetic recording devices obtained by changing the substrate for the magnetic disk and the spacer as shown in Table 1 were used to measure the maximum amplitude and the fluttering properties. The results are shown in Table 1.

Spacer: The diameter of the outer circumferential surface was 32 mm, the diameter of the inner circumferential surface was 25 mm, the thickness was 1.8 mm, and the chamfered surfaces were formed such that the lengths in the radial direction were 250 μm on both the inner and outer circumference sides and the angle with respect to the inner and outer circumferential surfaces was 45 degrees. Widths L of the main surfaces were 3.0 mm.

Magnetic disk: A magnetic film and the like were formed on a substrate having a diameter of 97 mm, an inner diameter of 25 mm, and a thickness of 0.5 mm or 0.45 mm.

[0094] [Table 1]

	Substrate	Spacer	CTE(sub) ($\times 10^{-7}/K$)	CTE(spa) ($\times 10^{-7}/K$)	E(sub) (GPa)	E(spa) (GPa)	Thickness (sub) (mm)	Density (spa) (g/cm ³)	CTE(sub) / E(sub)	[CTE(sub)*E(spa) / [CTE(spa)*E(sub)]	CTE(sub)*E(sub) ($\times 10^4$)	CTE(spa)*E(spa) ($\times 10^4$)	Maximum amplitude (mm)	Fluttering value F (mm)	Fluttering properties F:D
Ex. 1	SU-1	SP-1	37	33	83	65	0.5	2.23	0.45	0.88	0.3071	0.2145	0.15	78.3	39.2
Ex. 2	SU-2	SP-1	35	33	83	65	0.45	2.23	0.42	0.83	0.2905	0.2145	0.18	91.2	41.0
Ex. 3	SU-3	SP-1	45	33	98	65	0.45	2.23	0.46	0.90	0.441	0.2145	0.15	93.7	42.2
Ex. 4	SU-1	SP-2	37	93	83	116	0.45	4.5	0.45	0.56	0.3071	1.0788	0.22	99.6	44.8
Ex. 5	SU-1	SP-3	37	94	83	71	0.5	2.5	0.45	0.34	0.3071	0.6674	0.24	81.5	40.8
Ex. 6	SU-4	SP-3	95	94	79	71	0.5	2.5	1.20	0.91	0.7505	0.6674	0.21	83.8	41.9
Ex. 7	SU-2	SP-7	35	108	83	206	0.45	7.75	0.42	0.80	0.2905	2.2248	0.25	96.7	43.5
Comp. Ex. 1	SU-4	SP-1	95	33	79	65	0.5	2.23	1.20	2.37	0.7505	0.2145	0.30	86.2	43.1
Comp. Ex. 2	SU-5	SP-4	80	80	83	83	0.5	2.43	0.96	1.00	0.664	0.664	0.27	85.4	42.7
Comp. Ex. 3	SU-6	SP-5	70	70	83	83	0.45	2.35	0.84	1.00	0.581	0.581	0.28	103.2	46.4
Comp. Ex. 4	SU-7	SP-6	30	30	83	83	0.45	2.21	0.36	1.00	0.249	0.249	0.27	101.4	45.6
Comp. Ex. 5	SU-4	SP-2	95	93	79	116	0.45	4.5	1.20	1.50	0.7505	1.0788	0.29	100.5	45.2

[0095] The codes in the table have the following meanings.

(Substrate)

SU-1: Glass substrate (made of alkali-free glass with a Young's modulus of 83 GPa and a coefficient of thermal expansion of $37 \times 10^{-7}/\text{K}$)

5 SU-2: Glass substrate (made of alkali-free glass with a Young's modulus of 83 GPa and a coefficient of thermal expansion of $35 \times 10^{-7}/\text{K}$)

SU-3: Glass substrate (made of alkali-containing glass with a Young's modulus of 98 GPa and a coefficient of thermal expansion of $45 \times 10^{-7}/\text{K}$)

10 SU-4: Glass substrate (made of alkali-containing glass with a Young's modulus of 79 GPa and a coefficient of thermal expansion of $95 \times 10^{-7}/\text{K}$)

SU-5: Glass substrate (made of alkali-containing glass with a Young's modulus of 83 GPa and a coefficient of thermal expansion of $80 \times 10^{-7}/\text{K}$)

SU-6: Glass substrate (made of alkali-containing glass with a Young's modulus of 83 GPa and a coefficient of thermal expansion of $70 \times 10^{-7}/\text{K}$)

15 SU-7: Glass substrate (made of alkali-free glass with a Young's modulus of 83 GPa and a coefficient of thermal expansion of $30 \times 10^{-7}/\text{K}$)

(Spacer)

SP-1: Glass spacer (made of glass with a Young's modulus of 65 GPa and a coefficient of thermal expansion of $33 \times 10^{-7}/\text{K}$)

20 SP-2: Ti spacer (made of Ti metal with a Young's modulus of 116 GPa and a coefficient of thermal expansion of $93 \times 10^{-7}/\text{K}$)

SP-3: Glass spacer (made of glass with a Young's modulus of 71 GPa and a coefficient of thermal expansion of $94 \times 10^{-7}/\text{K}$)

25 SP-4: Glass spacer (made of alkali-containing glass with a Young's modulus of 83 GPa and a coefficient of thermal expansion of $80 \times 10^{-7}/\text{K}$ (the same glass as the glass for the glass substrate SU-5))

SP-5: Glass spacer (made of alkali-containing glass with a Young's modulus of 83 GPa and a coefficient of thermal expansion of $70 \times 10^{-7}/\text{K}$ (the same glass as the glass for the glass substrate SU-6))

30 SP-6: Glass spacer (made of alkali-free glass with a Young's modulus of 83 GPa and a

coefficient of thermal expansion of $30 \times 10^{-7}/\text{K}$ (the same glass as the glass for the glass substrate SU-7))

SP-7: Stainless steel spacer (made of 19Cr ferrite-based stainless steel with a Young's modulus of 206 GPa and a coefficient of thermal expansion of $108 \times 10^{-7}/\text{K}$)

5 List of Reference Numerals

[0096] 1...Magnetic recording device, 2...Laminated structure, 21...Magnetic disk, 22...Spacer, 23...Spindle, 24...Clamp member, 211...Substrate, 213...Magnetic recording layer, 215...Spindle hole, 216...Main surface, 225...Spindle hole, 226...Main surface, 241...Protrusion, 3...Head assembly, 31...Head slider

CLAIMS

[Claim 1] A magnetic recording device comprising:

a plurality of magnetic disks that each include a substrate having a thickness of 0.51
5 mm or less and a magnetic recording layer formed on the substrate; and

a spacer that is disposed between the plurality of magnetic disks and is used to layer
the magnetic disks at a predetermined interval,

wherein the substrate and the spacer satisfy an expression (1):

$$[\text{CTE}(\text{sub}) \cdot \text{E}(\text{spa})] / [\text{CTE}(\text{spa}) \cdot \text{E}(\text{sub})] < 1.0 \cdots (1)$$

10 (where

CTE(sub) is a coefficient of thermal expansion ($\times 10^{-7}/\text{K}$) of the substrate at 100°C
to 300°C,

CTE(spa) is a coefficient of thermal expansion ($\times 10^{-7}/\text{K}$) of the spacer at 100°C to
300°C,

15 E(sub) is a Young's modulus (GPa) of the substrate, and

E(spa) is a Young's modulus (GPa) of the spacer).

[Claim 2] The magnetic recording device according to claim 1,

wherein the substrate and the spacer satisfy an expression (2):

20 $0.30 \leq [\text{CTE}(\text{sub}) \cdot \text{E}(\text{spa})] / [\text{CTE}(\text{spa}) \cdot \text{E}(\text{sub})] \cdots (2).$

[Claim 3] The magnetic recording device according to claim 1,

wherein the spacer satisfies an expression (3):

$$\text{CTE}(\text{spa}) \cdot \text{E}(\text{spa}) \leq 1.0 \times 10^4 \cdots (3).$$

25

[Claim 4] The magnetic recording device according to claim 1,

wherein the substrate satisfies an expression (4):

$$\text{CTE}(\text{sub}) \cdot \text{E}(\text{sub}) \leq 0.5 \times 10^4 \cdots (4).$$

30 [Claim 5] The magnetic recording device according to claim 1,

wherein the substrate is a glass substrate,
the glass substrate satisfies the expression (5):

$$\text{CTE}(\text{sub}) / E(\text{sub}) \leq 1.5 \cdots (5), \text{ and}$$

a glass composition of the glass substrate contains

5 SiO₂ in an amount of 55 mol% to 80 mol%, Al₂O₃ in an amount of 5 mol%
to 25 mol%, B₂O₃ in an amount of 0 mol% to 8 mol%, MO in an amount of 5 mol% to 25
mol% (MO is at least one selected from MgO, CaO, SrO, and BaO, and the content thereof
is the sum of the contents of MgO, CaO, SrO, and BaO), and M₂O in an amount of 0 mol%
to 15 mol% (M₂O is at least one selected from Li₂O, Na₂O, and K₂O, and the content thereof
10 is the sum of the contents of Li₂O, Na₂O, and K₂O).

[Claim 6] The magnetic recording device according to claim 1,

 wherein when impact is applied to each of the magnetic disks installed in the
magnetic recording device under conditions of 2 [msec] and 40 [G] in a normal direction of
15 main surfaces of the magnetic disk, the maximum amplitude of vibration in a thickness
direction of the outer circumferential end portion of the magnetic disk is 0.25 mm or less.

[Claim 7] A laminated structure comprising:

 a plurality of magnetic disks that each include a substrate having a thickness of 0.51
20 mm or less and a magnetic recording layer formed on the substrate; and

 a spacer that is disposed between the plurality of magnetic disks and is used to layer
the magnetic disks at a predetermined interval,

 wherein the substrate and the spacer satisfy an expression (1):

$$[\text{CTE}(\text{sub}) \cdot E(\text{spa})] / [\text{CTE}(\text{spa}) \cdot E(\text{sub})] < 1.0 \cdots (1)$$

25 (where

 CTE(sub) is a coefficient of thermal expansion ($\times 10^{-7}/\text{K}$) of the substrate at 100°C
to 300°C,

 CTE(spa) is a coefficient of thermal expansion ($\times 10^{-7}/\text{K}$) of the spacer at 100°C to
300°C,

30 E(sub) is a Young's modulus (GPa) of the substrate, and

$E(\text{spa})$ is a Young's modulus (GPa) of the spacer).

[Claim 8] The laminated structure according to claim 7,
wherein the substrate and the spacer satisfy an expression (2):

$$0.30 \leq [\text{CTE}(\text{sub}) \cdot E(\text{spa})] / [\text{CTE}(\text{spa}) \cdot E(\text{sub})] \cdots (2).$$

[Claim 9] The laminated structure according to claim 7,
wherein the spacer satisfies an expression (3):

$$\text{CTE}(\text{spa}) \cdot E(\text{spa}) \leq 1.0 \times 10^4 \cdots (3).$$

[Claim 10] The laminated structure according to claim 7,
wherein the substrate satisfies an expression (4):

$$\text{CTE}(\text{sub}) \cdot E(\text{sub}) \leq 0.5 \times 10^4 \cdots (4).$$

[Claim 11] The laminated structure according to claim 7,
wherein the substrate is a glass substrate,
the glass substrate satisfies the expression (5):

$$\text{CTE}(\text{sub}) / E(\text{sub}) \leq 1.5 \cdots (5), \text{ and}$$

a glass composition of the glass substrate contains

SiO_2 in an amount of 55 mol% to 80 mol%, Al_2O_3 in an amount of 5 mol% to 25 mol%, B_2O_3 in an amount of 0 mol% to 8 mol%, MO in an amount of 5 mol% to 25 mol% (MO is at least one selected from MgO, CaO, SrO, and BaO, and the content thereof is the sum of the contents of MgO, CaO, SrO, and BaO), and M_2O in an amount of 0 mol% to 15 mol% (M_2O is at least one selected from Li_2O , Na_2O , and K_2O , and the content thereof is the sum of the contents of Li_2O , Na_2O , and K_2O).